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High Energy Theory Group

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Research Activities

(I) Quantum Chromodynamics

a. *Calculating the pion decay constant from $\alpha_s(M_Z)$*
(M. Hashimoto and M. Tanabashi)

We revisit the analysis of the improved ladder Schwinger-Dyson (SD) equation for the dynamical chiral symmetry breaking in QCD with emphasizing the importance of the scale ambiguity. Previous calculation done so far naively used one-loop $\overline{\rm MS}$ coupling in the improved ladder SD equation without examining the scale ambiguity. As a result, the calculated pion decay constant f_π was less than a half of its experimental value $f_\pi = 92.4\,\mathrm{MeV}$ once the QCD scale is fixed from the high energy coupling $\alpha_s^{\overline{\rm MS}}(M_Z)$. In order to settle the ambiguity in a proper manner, we adopt here in the present paper the next-to-leading-order effective coupling instead of a naive use of the $\overline{\rm MS}$ coupling. The pion decay constant f_π is then calculated from high energy QCD coupling strength $\alpha_s^{\overline{\rm MS}}(M_Z) = 0.1172 \pm 0.0020$. Within the Higashijima-Miransky approximation, we obtain $f_\pi = 85$–$106\,\mathrm{MeV}$ depending on

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the value of $\alpha_s^{\overline{\rm MS}}(M_Z)$ which agrees well with the experimentally observed value $f_\pi = 92.4\,\mathrm{MeV}$. The validity of the improved ladder SD equation is therefore ascertained more firmly than considered before.

b. *π^+–π^0 mass difference in the hidden local symmetry: A dynamical origin of little Higgs*
(M. Harada, M. Tanabashi, and K. Yamawaki)

We calculate π^+–π^0 mass difference $\Delta m_\pi^2 \equiv m_{\pi^+}^2 - m_{\pi^0}^2$ in the Hidden Local Symmetry (HLS) model, based on the Wilsonian matching and Wilsonian renormalization-group equations. Even without a_1 meson the result agrees well with the experiment in sharp contrast to the conventional approach where the a_1 meson plays a crucial role. For large N_f QCD, there arises a large hierarchy between Δm_π^2 and the π decay constant F_π^2, $\Delta m_\pi^2/F_\pi^2 \ll 1$, near the critical point where the chiral symmetry gets restored as the vector manifestation and the HLS model becomes a little Higgs model with two sites and two links, with the dynamically generated gauge coupling of the composite ρ becoming vanishingly small.

c. *Improved perturbative QCD approach to the bottomonium spectrum* [3]
(S. Recksiegel and Y. Sumino)

Recently it has been shown that the gross structure of the bottomonium spectrum is reproduced reasonably well within the non-relativistic boundstate theory based on perturbative QCD. In that calculation, however, the fine splittings and the S–P level splittings are predicted to be considerably narrower than the corresponding experimental values. We investigate the bottomonium spectrum within a specific framework based on perturbative QCD, which incorporates all the corrections up to $\mathcal{O}(\alpha_S^5 m_b)$ and $\mathcal{O}(\alpha_S^4 m_b)$, respectively, in the computations of the fine splittings and the S–P splittings. We find that the agreement with the experimental data for the fine splittings improves drastically due to an enhancement of the wave functions close to the origin as compared to the Coulomb wave functions. The agreement of the S–P splittings with the experimental data also becomes better. We find that natural scales of the fine splittings and the S–P splittings are larger than those of the boundstates themselves. On the other hand, the predictions of the level spacings between consecutive principal quantum numbers depend rather strongly on the scale μ of the operator $\propto C_A/(m_b r^2)$. The agreement of the whole spectrum with the experimental data is much better than the previous predictions when $\mu \approx 3$–4 GeV for $\alpha_S(M_Z) = 0.1181$. There seems to be a phenomenological preference for some suppression mechanism for the above operator.

d. *Understanding heavy quarkonium systems in perturbative QCD*
(Y. Sumino)

We review the recent theoretical progress in heavy quarkonium spectroscopy within the boundstate theory based on perturbative QCD. New microscopic pictures of the heavy quarkonium systems are obtained.

e. *Comparing the QCD potential in perturbative QCD and lattice QCD at large distances*
(S. Recksiegel and Y. Sumino)

We compare the perturbatively calculated QCD potential to that obtained from lattice calculations in the theory without light quark flavours. We examine $E_{\rm tot}(r) = 2m_{\rm pole} + V_{\rm QCD}(r)$ by re-expressing it in the $\overline{\rm MS}$ mass $\overline{m} \equiv m^{\overline{\rm MS}}(m^{\overline{\rm MS}})$ and by choosing specific prescriptions for fixing the scale μ (dependent on r and m). By adjusting m so as to maximise the range of convergence, we show that perturbative and lattice calculations agree up to $3\,r_0 = 7.5\,{\rm GeV}^{-1}$ (r_0 is the Sommer scale) within the perturbative uncertainty of order $\Lambda_{\rm QCD}^3\,r^2$.

f. *QCD potential as a 'Coulomb-plus-linear' potential*
(Y. Sumino)

We show analytically that the QCD potential can be expressed, up to an $\mathcal{O}(\Lambda_{\rm QCD}^3 r^2)$ uncertainty, as the sum of a "Coulomb" potential (with log corrections at short distances) and a linear potential, within an approximation based on perturbative expansion in α_S and the renormalon dominance picture. The expansion of $V_{\rm QCD}(r)$ is truncated at $\mathcal{O}(\alpha_S^N)$ $[N = 6\pi/(\beta_0\alpha_S)]$, where the term becomes minimal according to the estimate by NLO renormalon, and is studied for $N \gg 1$. Analytic expressions for the linear potential are obtained in some cases.

(II) Top Quark Physics

a. *Kinematical reconstruction of the $t\bar{t}$ system near its threshold at future e^+e^- colliders* [4]
(K. Ikematsu, K. Fujii, Z. Hioki, Y. Sumino, and T. Takahashi)

We developed a new method for full kinematical reconstruction of the $t\bar{t}$ system near its threshold at future linear e^+e^- colliders. In the core of the method lies likelihood fitting which is designed to improve measurement accuracies of the kinematical variables that specify the final states resulting from $t\bar{t}$ decays. The improvement is demonstrated by applying this method to a Monte-Carlo $t\bar{t}$ sample generated with various experimental effects including beamstrahlung, finite acceptance and resolution of the detector system, etc. A possible application of this method and its expected impact are also discussed.

b. *Top mass determination and $\mathcal{O}(\alpha_S^5 m)$ correction to toponium $1S$ energy level* [5]
(Y. Kiyo and Y. Sumino)

Recently the full $\mathcal{O}(\alpha_S^5 m, \alpha_S^5 m \log\alpha_S)$ correction to the heavy quarkonium $1S$ energy level has been computed (except the a_3-term in the QCD potential). We point out that the full correction (including the $\log\alpha_S$-term) is approximated well by the large-β_0 approximation. Based on the assumption that this feature holds up to higher orders, we discuss why the top quark pole mass cannot be determined to better than $\mathcal{O}(\Lambda_{\rm QCD})$ accuracy at a future e^+e^- collider, while the $\overline{\rm MS}$ mass can be determined to about 40 MeV accuracy (provided the 4-loop $\overline{\rm MS}$-pole mass relation will be computed in due time).

c. *Top quark and QCD physics at e^+e^- linear colliders: Recent progress*
(Y. Sumino)

I review the studies, which were reported after the last Linear Collider Workshop, on top quark physics and QCD physics at a future e^+e^- linear collider.

d. *How well can we reconstruct the $t\bar{t}$ system near its threshold at future e^+e^- colliders?*
(K. Ikematsu, K. Fujii, Z. Hioki, Y. Sumino, and T. Takahashi)

We developed a new method for full kinematical reconstruction of the $t\bar{t}$ system near its threshold at future linear e^+e^- colliders. In the core of the method lies likelihood fitting which is designed to improve measurement accuracies of the kinematical variables that specify the final states resulting from $t\bar{t}$ decays. The improvement is demonstrated by applying this method to a Monte-Carlo $t\bar{t}$ sample generated with various experimental effects including beamstrahlung, finite acceptance and resolution of the detector system, *etc.* In most cases the fit brings a broad non-Gaussian distribution of a given kinematical variable to a nearly Gaussian shape, thereby justifying phenomenological analyses based on simple Gaussian smearing of parton-level momenta. The standard deviations of the resultant distributions of various kinematical variables are given in order to facilitate such phenomenological analyses. A possible application of the kinematical fitting method and its expected impact are also discussed.

(III) Supersymmetry

a. *Recent muon $g-2$ result in deflected anomaly-mediated supersymmetry breaking*
(N. Abe and M. Endo)

We study the deflected anomaly-mediated supersymmetry breaking (AMSB) scenario in the light of the recent result of the muon $g-2$ from Brookhaven E821 experiment. The E821 result suggests the deviation from the SM prediction, though there remain unsettled uncertainties. We find that the supersymmetric contribution to the muon $g-2$ can be $\mathcal{O}(10^{-9})$, large enough to fill the deviation, with other experimental constraints satisfied. In particular, the Higgs mass and $b \to s\gamma$ put severe constraints on the model and large $\tan\beta$ is favored to enhance the muon $g-2$.

b. *Top-squark study at a future e^+e^- linear collider* [7]
(R. Kitano, T. Moroi, and S.-f. Su)

We discuss a potential of studying the production and the decay of the lightest top squark ($\tilde{t}_1$) in the framework of the supersymmetric standard model at a future e^+e^- collider. In particular, we consider the process $\tilde{t}_1 \to t\chi_1^0$ (with χ_1^0 being the lightest neutralino) followed by $t \to bW$. It is shown that, by the study of the angular distribution of the bottom quark (as well as the production cross section of the top squark), properties of χ_1^0 can be extracted. We also discuss that, if χ_1^0 is gaugino-like, the neutralino mixing parameters (*i.e.*, the so-called μ-parameter and $\tan\beta$) may be constrained.

c. *3- and 2-body supersymmetric processes: Predictions, challenges and prospectives* [9]
(F. Borzumati, J. S. Lee, and F. Takayama)

The processes subject of this talk are: 1) the $2 \to 3$ processes contributing, together with the $2 \to 2$ one to the hadron-collider production of a charged Higgs boson in association with a t-quark; 2) the $2 \to 2$ and $2 \to 3$ processes giving rise to the hadron-collider strahlung of a charged slepton from a t-quark in R_p-violating models in which lepton-number-violating trilinear couplings largely dominate over bilinear ones; 3) 3-body neutralino and chargino decays in similar R_p-violating scenarios. The significance of the R_p-violating processes is critically assessed against implications from neutrino physics. Contributions to neutrino masses arising at the tree level, at the one- and two-loop levels are reviewed. Comments are also made on the production of sneutrinos via gluon fusion and on the decay of sneutrinos into photons pairs, and on the influence that constraints from neutrino physics have on these processes.

d. *Phenomenology of minimal supergravity with vanishing A and B soft supersymmetry-breaking parameters* [10]
(M. Endo, M. Matsumura, and M. Yamaguchi)

The ansatz of vanishing A and B parameters eliminates CP violating complex phases in soft supersymmetry-breaking parameters of the minimal supersymmetric standard model, and thus provides a simple solution to the supersymmetry CP problem. Phenomenological implications of this ansatz are investigated in the framework of minimal supergravity. We show that electroweak symmetry breakdown occurs, predicting relatively large $\tan\beta$. The ansatz survives the Higgs mass bound as well as the $b \to s\gamma$ constraint if the universal gaugino mass is larger than 300 GeV. We also find that the supersymmetric contribution to the anomalous magnetic moment of muon lies in an experimentally interesting region of order 10^{-9} in a large portion of the parameter space.

e. *Dynamical solution to supersymmetric CP problem with vanishing B parameter* [11]
(M. Yamaguchi and K. Yoshioka)

The CP violation gives rise to severe restriction of soft breaking terms in supersymmetric standard models. Among them, constraints on the holomorphic soft mass of Higgs doublets (the B parameter) are difficult to satisfy due to the other inherent problem in the Higgs potential; the μ problem. In this letter, it is argued that these CP and μ problems can be rather relaxed provided that B is vanishing at high-energy scale. A generic mechanism and some examples of model are presented to dynamically realize this condition by introducing gauge singlet fields.

f. *Flavor violation in supersymmetric theories with gauged flavor symmetries*
(T. Kobayashi, H. Nakano, H. Terao, and K. Yoshioka)

In this paper we study flavor violation in supersymmetric models with gauged flavor symmetries. There are several sources of flavor violation in these theories. The dominant flavor violation is the tree-level D-term contribution to scalar masses

generated by flavor symmetry breaking. We present a new approach for suppressing this phenomenologically dangerous effects by separating the flavor-breaking sector from supersymmetry-breaking one. The separation can be achieved in geometrical setups or in a dynamical way. We also point out that radiative corrections from the gauginos of gauged flavor symmetries give sizable generation-dependent masses of scalars. The gaugino mass effects are generic and not suppressed even if the dominant D-term contribution is suppressed. We also analyze the constraints on the flavor symmetry sector from these flavor-violating corrections.

g. *Democratic (s)fermions and lepton flavor violation*
(K. Hamaguchi, M. Kakizaki, and M. Yamaguchi)

The democratic approach to account for fermion masses and mixing is known to be successful not only in the quark sector but also in the lepton sector. Here we extend this ansatz to supersymmetric standard models, in which the Kähler potential obeys underlying S_3 flavor symmetries. The requirement of neutrino bi-large mixing angles constrains the form of the Kähler potential for left-handed lepton multiplets. We find that right-handed sleptons can have non-degenerate masses and flavor mixing, while left-handed sleptons are argued to have universal and hence flavor-blind masses. This mass pattern is testable in future collider experiments when superparticle masses will be measured precisely. Lepton flavor violation arises in this scenario. In particular, $\mu \to e\gamma$ is expected to be observed in a planning future experiment if supersymmetry breaking scale is close to the weak scale.

h. *Scale- and gauge-independent mixing angles for scalar particles* [14]
(J. R. Espinosa and Y. Yamada)

The existing definitions of mixing angles (one-loop radiatively corrected and renormalization-scale independent) for scalar particles turn out to be gauge dependent when used in gauge theories. We show that a scale- and gauge-independent mixing angle can be obtained if the scalar self-energy is improved by the pinch technique, and give two relevant examples in the Minimal Supersymmetric Standard Model: the mixing of CP-even Higgs scalars and of top squarks. We also show that the recently proposed definition of mixing angle that uses the (unpinched) scalar two-point function evaluated at a particular value of the external momentum [$p_*^2 = (M_1^2 + M_2^2)/2$, where $M_{1,2}$ are the masses of the mixed particles] computed in the Feynman gauge coincides with the gauge-invariant pinched result. In alternative definitions (*e.g.* in the on-shell scheme), the improved Higgs mixing angle is different from that in the Feynman gauge. Some freedom in the pinch technique for scalar-scalar-gauge couplings is also discussed.

(IV) Extra Spacetime Dimensions

a. *Field localization in warped gauge theories* [15]
(H. Abe, T. Kobayashi, N. Maru, and K. Yoshioka)

We present four-dimensional gauge theories that describe physics on five-dimensional curved (warped) backgrounds, which includes bulk fields with various spins (vectors, spinors, and scalars). Field theory on the AdS_5 geometry is examined as a simple example of our formulation. Various properties of bulk fields on this background, e.g., the mass spectrum and field localization behavior, can be achieved within a fully four-dimensional framework. Moreover, that gives a localization mechanism for massless vector fields. We also consider supersymmetric cases, and show in particular that the conditions on bulk masses imposed by supersymmetry on warped backgrounds are derived from a four-dimensional supersymmetric theory on the flat background. As a phenomenological application, models are shown to generate hierarchical Yukawa couplings. Finally, we discuss possible underlying mechanisms which dynamically realize the required couplings to generate curved geometries.

b. *Superfield description of effective theories on BPS domain walls* [17]
(Y. Sakamura)

We derive the low-energy effective theory on the BPS domain wall in 4D N=1 global SUSY theories in terms of the 3D superfields. Our derivation makes the preserved SUSY by the wall manifest and the procedure for integrating out the massive modes easier. Our procedure clarifies how the 3D superfields are embedded into the 4D chiral and vector superfields. We also point out a shortcoming of the conventional procedure for deriving the effective theory on the wall.

c. *Modified mode-expansion on a BPS wall related to the nonlinear realization* [18]
(Y. Sakamura)

We propose a modified mode-expansion of the bulk fields in a BPS domain wall background to obtain the effective theory on the wall. The broken SUSY is nonlinearly realized on each mode defined by our mode-expansion. Our work clarifies a relation between two different approaches to derive the effective theory on a BPS wall, *i.e.,* the nonlinear realization approach and the mode-expansion approach. We also discuss a further modification that respects the Lorentz and $U(1)_R$ symmetries broken by the wall.

(V) Particle Cosmology

a. *Cosmic density perturbations from late-decaying scalar condensations* [19]
(T. Moroi and T. Takahashi)

We study the cosmic density perturbations induced from fluctuation of the amplitude of late-decaying scalar condensations (called ϕ) in the scenario where the scalar field ϕ once dominates the universe. In such a scenario, the cosmic microwave

background (CMB) radiation originates to decay products of the scalar condensation and hence its anisotropy is affected by the fluctuation of ϕ. It is shown that the present cosmic density perturbations can be dominantly induced from the primordial fluctuation of ϕ, not from the fluctuation of the inflaton field. This scenario may change constraints on the source of the density perturbations, like inflation. In addition, a correlated mixture of adiabatic and isocurvature perturbations may arise in such a scenario; possible signals in the CMB power spectrum are discussed. We also show that the simplest scenario of generating the cosmic density perturbations only from the primordial fluctuation of ϕ (*i.e.*, so-called "curvaton" scenario) is severely constrained by the current measurements of the CMB angular power spectrum if correlated mixture of the adiabatic and isocurvature perturbations are generated.

b. *CMB anisotropy from baryogenesis by a scalar field* [20]
(T. Moroi and H. Murayama)

We study the cosmic microwave background (CMB) anisotropy in the scenario where the baryon asymmetry of the universe is generated from a condensation of a scalar field. In such a scenario, the scalar condensation may acquire fluctuation during the inflation which becomes a new source of the cosmic density perturbations. In particular, the primordial fluctuation of the scalar condensation may induce correlated mixture of the adiabatic and isocurvature fluctuations. If the scalar condensation decays before it completely dominates the universe, the CMB angular power spectrum may significantly deviate from the conventional adiabatic result. Such a deviation may be observed in the on-going MAP experiment.

(VI) Gravity and Black Holes

a. *Holographic charge excitation on a horizontal boundary* [21]
(M. Hotta)

We argue that states with nontrivial horizontal charges of BTZ black hole can be excited by ordinary falling matter including Hawking radiation. The matter effect does not break the integrability condition of the charges on the horizon. Thus we are able to trace the proccesses in which the matter imprints the information on the horizon by use of the charged states. It is naturally expected that in the thermal equilibrium with the Hawking radiation the black hole wanders ergodically through different horizontal states due to thermal fluctuation of incoming matter. This fact strengthens plausibility of the basic part of Carlip's idea. We also discuss some aspects of the quantum horizontal symmetry and conjecture how the precise black hole entropy will be given from our point of view.

(VII) String Theory and Related Topics

a. *Novel construction of boundary states in coset conformal field theories* [23]
(H. Ishikawa and T. Tani)

We develop a systematic method to solve the Cardy condition for the coset conformal field theory G/H. The problem is equivalent to finding a non-negative integer valued matrix representation (NIM-rep) of the fusion algebra. Based on the relation of the G/H theory with the tensor product theory $G \times H$, we give a map from NIM-reps of $G \times H$ to those of G/H. Our map provides a large class of NIM-reps in coset theories. In particular, we give some examples of NIM-reps not factorizable into the G and the H sectors. The action of the simple currents on NIM-reps plays an essential role in our construction. As an illustration of our procedure, we consider the diagonal coset $\mathrm{SU}(2)_5 \times \mathrm{SU}(2)_3/\mathrm{SU}(2)_8$ to obtain a new NIM-rep based on the conformal embedding $su(2)_3 \oplus su(2)_8 \subset sp(6)_1$.

b. *Twisted boundary states in $c = 1$ coset conformal field theories*
(H. Ishikawa and A. Yamaguchi)

We study the mutual consistency of twisted boundary conditions in the coset conformal field theory G/H. We calculate the overlap of the twisted boundary states of G/H with the untwisted ones, and show that the twisted boundary states are consistently defined in the diagonal modular invariant. The overlap of the twisted boundary states is expressed by the branching functions of a twisted affine Lie algebra. As a check of our argument, we study the diagonal coset theory $so(2n)_1 \oplus so(2n)_1/so(2n)_2$, which is equivalent with the orbifold S^1/Z_2. We construct the boundary states twisted by the automorphisms of the unextended Dynkin diagram of $so(2n)$, and show their mutual consistency by identifying their counterpart in the orbifold. For the triality of $so(8)$, the twisted states of the coset theory correspond to neither the Neumann nor the Dirichlet boundary states of the orbifold and yield the conformal boundary states that preserve only the Virasoro algebra.

c. *BPS Solutions of noncommutative gauge theories in four and eight dimensions*
(Y. Hiraoka)

We study the 1/4 BPS equations in the eight dimensional noncommutative Yang-Mills theory found by Bak, Lee and Park. We explicitly construct some solutions of the 1/4 BPS equations using the noncommutative version of the ADHM-like construction in eight dimensions. From the calculation of topological charges, we show that our solutions can be interpreted as the bound states of the D0-D4-D8 with a B-field. We also discuss the structure of the moduli space of the 1/4 BPS solutions and determine the metric of the moduli space of the U(2) one-instanton in four and eight dimensions.

d. *Noncommutative U(1) instantons in eight dimensional Yang-Mills theory*
(Y. Hiraoka)

We study the noncommutative version of the extended ADHM construction in the eight dimensional U(1) Yang-Mills theory. This construction gives rise to

the solutions of the BPS equations in the Yang-Mills theory, and these solutions preserve at least 3/16 of supersymmetries. In a wide subspace of the extended ADHM data, we show that the integer k which appears in the extended ADHM construction should be interpreted as the D4-brane charge rather than the D0-brane charge by explicitly calculating the topological charges in the case that the noncommutativity parameter is anti-self-dual. We also find the relationship with the solution generating technique and show that the integer k can be interpreted as the charge of the D0-brane bound to the D8-brane with the B-field in the case that the noncommutativity parameter is self-dual.

(VIII) Quantum Hall System

a. *Phase diagram of interacting composite fermions in the bilayer $\nu = 2/3$ quantum hall effect* [30]
(N. Kumada, D. Terasawa, Y. Shimoda, H. Azuhata, A. Sawada, Z. F. Ezawa, K. Muraki, T. Saku, and Y. Hirayama)

We measured the magnetoresistance of bilayer quantum Hall (QH) effects at the fractional filling factor $\nu = 2/3$ by changing the total electron density and the density difference between two layers. Three different QH states with a no-QH area and two types of hysteresis were observed. One of the hystereses is specific to bilayer systems. These phases are described well by a composite fermion model extended to a bilayer system.

b. *Grassmannian fields and doubly enhanced skyrmions in the bilayer quantum Hall system at $\nu = 2$* [31]
(K. Hasebe and Z. F. Ezawa)

At the filling factor $\nu = 2$ the bilayer quantum Hall system has three phases, the ferromagnetic phase (spin phase), the spin singlet phase (ppin phase) and the canted antiferromagnetic phase. We analyze soft waves and quasiparticle excitations in the spin and ppin phases. It is shown that the dynamic field is the Grassmannian $G_{4,2}$ field carrying four complex degrees of freedom. In each phase there are four complex soft waves (pseudo-Goldstone modes) and one kind of skyrmion excitations ($G_{4,2}$ skyrmions) flipping either spins or pseudospins coherently. An intriguing property is that a quasiparticle is a $G_{4,2}$ skyrmion essentially consisting of two CP^3 skyrmions and thus possesses charge $2e$.

c. *Continuous transformation from spin- to pseudospin-type excitation*
(A. Sawada, D. Terasawa, N. Kumada, M. Morino, K. Tagasira, Z. F. Ezawa, K. Muraki, T. Saku, and Y. Hirayama)

We measured the activation energy of bilayer $\nu = 1$ quantum Hall states. By changing the density difference between layers, the tilting behavior of the pseudospin (P)-type activation energy at the equal density point gradually transforms into the spin (S)-type one at the monolayer density point. At the intermediate density difference, by increasing the tilting angle the activation energy starts to decrease as the P-type excitation gap and then increases as the S-type excitation gap. It

is impossible to explain this behavior by the level crossing of the P- and S-type excitations. The result of the overall behavior indicates the excitation in a bilayer system is the simultaneous flip of spin and pseudospin.

d. *Noncommutative geometry, extended W_∞ algebra and Grassmannian solitons in multicomponent quantum Hall systems* [32]
(Z. F. Ezawa, G. Tsitsishvili, and K. Hasebe)

Noncommutative geometry governs the physics of quantum Hall (QH) effects. We introduce the Weyl ordering of the second quantized density operator to explore the dynamics of electrons in the lowest Landau level. We analyze QH systems made of N-component electrons at the integer filling factor $\nu = k \leq N$. The basic algebra is the SU(N)-extended W_∞. A specific feature is that noncommutative geometry leads to a spontaneous development of SU(N) quantum coherence by generating the exchange Coulomb interaction. The effective Hamiltonian is the Grassmannian $G_{N,k}$ sigma model, and the dynamical field is the Grassmannian $G_{N,k}$ field, describing $k(N-k)$ complex Goldstone modes and one kind of topological solitons (Grassmannian solitons).

(IX) Miscellaneous

a. *Review of particle physics* [36]
(Particle Data Group, K. Hagiwara, K. Hikasa, K. Nakamura, M. Tanabashi, *et al.*)

This biennial Review summarizes much of Particle Physics. Using data from previous editions, plus 2205 new measurements from 667 papers, we list, evaluate, and average measured properties of gauge bosons, leptons, quarks, mesons, and baryons. We also summarize searches for hypothetical particles such as Higgs bosons, heavy neutrinos, and supersymmetric particles. All the particle properties and search limits are listed in Summary Tables. We also give numerous tables, figures, formulae, and reviews of topics such as the Standard Model, particle detectors, probability, and statistics. This edition features expanded coverage of CP violation in B mesons and of neutrino oscillations. For the first time we cover searches for evidence of extra dimensions (both in the particle listings and in a new review). Another new review is on Grand Unified Theories. A booklet is available containing the Summary Tables and abbreviated versions of some of the other sections of this full Review. All tables, listings, and reviews (and errata) are also available on the Particle Data Group website: `http://pdg.lbl.gov`.

Publications

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2) *Offshellness and boundstate of heavy quarks*, Y. Kiyo, in *Proceedings of the 7th Accelerator and Particle Physics Institute (APPI2002)*, Morioka, Japan, Feb. 2002 (KEK Proceedings, 2002), pp. 213–218.

3) *Improved perturbative QCD approach to the bottomonium spectrum*, S. Recksiegel and Y. Sumino, *Phys. Rev. D* **67**, 014004 (2003).

4) *Kinematical reconstruction of the $t\bar{t}$ system near its threshold at future e^+e^- colliders*, K. Ikematsu, K. Fujii, Z. Hioki, Y. Sumino, and T. Takahashi, in *Proceedings of the 7th Accelerator and Particle Physics Institute (APPI2002)*, Morioka, Japan, Feb. 2002 (KEK Proceedings, 2002), pp. 219–232.

5) *Top mass determination and $\mathcal{O}(\alpha_S^5 m)$ correction to toponium $1S$ energy level*, Y. Kiyo and Y. Sumino, *Phys. Rev. D* **67**, 071501 (2003).

6) *Next generation e^+e^- colliders and physics of top quark*, Y. Sumino, Butsuri **57**, No. 10 (2002) *(in Japanese)*.

7) *Top-squark study at a future e^+e^- linear collider*, R. Kitano, T. Moroi, and S.-f. Su, *JHEP* **0212**, 011 (2002).

8) *Lightest-neutralino decays in R_p-violating models with dominant λ' and λ couplings*, F. Borzumati, R. M. Godbole, J. L. Kneur, and F. Takayama, *JHEP* **0207**, 037 (2002).

9) *3- and 2-body supersymmetric processes: Predictions, challenges and prospectives*, F. Borzumati, J. S. Lee, and F. Takayama, in *Proceedings of the 7th Accelerator and Particle Physics Institute (APPI2002)*, Morioka, Japan, Feb. 2002 (KEK Proceedings, 2002), pp. 164–190.

10) *Phenomenology of minimal supergravity with vanishing A and B soft supersymmetry-breaking parameters*, M. Endo, M. Matsumura, and M. Yamaguchi, *Phys. Lett. B* **544**, 161–166 (2002).

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Doctoral Theses (March 2003)

D1) *An analysis of $\pi\pi$ scattering with N/D method and σ meson*, N. Akama.

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Master Theses (March 2003)

M1) *Analysis of nonstandard top quark interactions using final state neutrinos* (in Japanese), S. Matsui.

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